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Understanding Vehicle-to-Grid User Engagement Using Self-Determination Theory

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Abstract

With the proliferation of electric vehicles, smart charging and discharging technologies, such as vehicle-to-grid (V2G), are playing an increasingly important role. V2G can help improve grid efficiency, reduce greenhouse emissions, and help energy systems increase the share of volatile renewable energy sources. However, for the successful implementation of such technologies, active participation of the vehicle users is critical. So far, literature has mainly focused on the technical aspects of V2G, neglecting the human component., this paper follows a twofold approach. First, we conduct a systematic review of 458 articles on V2G. Second, we draw on the self-determination theory to deepen our understanding of the motivational drivers for adopting or paying for V2G services and how they can be strengthened. Our findings indicate that financial and environmental benefits are important drivers for V2G adoption. Additionally, clear policies, awareness programs, and developed infrastructure are essential for the widespread adoption of V2G systems.

Keywords: Vehicle-to-Grid, systematic literature review, user perspective, self-determination theory.

1 Introduction

Electric vehicles are an important building block in the efforts of governments around the world to combat climate change and reduce CO2 emissions (Baumgartner et al., 2022). Recent figures indicate that the number of electric vehicles sold worldwide has risen from 3.18 million to 10.25 million in 2022 (Statista, 2023). According to the International Energy Agency (2023), electric car sales are expected to reach a market share of 60 percent by 2030. To keep up with the transition goals, governments globally are implementing policies to stimulate people and businesses to actively participate in carbon-neutral efforts (Danish Energy Agency, 2022; IRENA, 2022).

Despite the urgency of decarbonizing the mobility sector and transitioning towards electric vehicles (Baumgartner et al., 2023; Saxena et al., 2023), these efforts do not come without challenges. An increasing share of electric vehicles (EVs) leads to higher electricity demand and intensified peak loads in the grid. At the same time, renewables are increasingly replacing fossil fuels, leading to greater volatility in energy production. One of the most promising technological solutions to help balance energy supply and demand and thereby support the stability of the grid is vehicle-to-grid (V2G) (Baumgartner et al., 2022). V2G is an emerging technology that refers to some type of smart charging and discharging technology that allows electric vehicles to serve as short-term mobile battery storage that can manage power flows in both directions (to and from the grid), reducing the need for electric utility infrastructure (Sovacool, Axsen and Kempton, 2017). It can also provide backup power for electric utilities, reduce peak loads (Kempton and Letendre, 1997; Letendre and Kempton, 2002) and help to utilize existing generation capacities more efficiently (Madzharov, Delarue and D'haeseleer, 2014). Widespread application of V2G could limit the indispensable grid expansion as well as reduce the investment in costly stationary battery storage (Després et al., 2017). For a

successful implementation of V2G, active user participation is needed (Baumgartner et al., 2023). Tacit consent is not enough, as users will need to set preferences for charging and discharging times via an app, for example (Saxena et al., 2023).

It comes as no surprise that V2G has attracted the attention of many scholars over the last decade. However, most studies have a technical focus (Sovacool et al., 2018) and therefore provide very little insight into user-related aspects of V2G (Sovacool, Axsen and Kempton, 2017) – especially in the information systems literature. This gap in the literature has been highlighted by Sovacool et al. (2018): of the 197 articles analyzed on V2G, very few addressed topics like range anxiety (1.1 percent) or consumer attitudes (2.1 percent). For this reason, our work aims to a better understanding of people's preferences and motivations for acceptance and usage of the technology to create necessary conditions and policies that would foster the adoption of V2G. This would be necessary for users of smart information systems to make more sustainable behavioral choices (Ijab, Molla and Kassahun, 2010). Based on the above, our research question is as follows:

What motivates individuals to use vehicle-to-grid technology as part of their smart charging strategy?

To uncover motivational drivers, we pursue a twofold research approach. In the first step, we conduct a systematic literature review (SLR) to identify and analyze relevant research on user preferences and willingness to accept and participate in V2G. Due to the dynamic developments in the field of V2G technology, we limit our research to articles published in the past five years, covering the period from 2018 to October 2023. In the second step, we draw on self-determination theory (Ryan and Deci, 2000) to investigate what drives users' motivation to participate in V2G and suggest how it can be reinforced. With this research, we seek to enrich the literature on green information systems and provide policymakers and grid operators with new insights into what moves people to make more sustainable decisions and use smart charging and discharging technologies.

The remainder of the paper is organized as follows: In Section 2, we introduce the concept of vehicle-to-grid technology as well as the self-determination theory, which serves as the theoretical foundation for our study. In Section 3, we describe the process of the SLR and present the criteria we used to select papers for our analysis and its results. Following this and building on self-determination theory, Section 4 uncovers the motivational statements and places them along the self-determination continuum. Next, we discuss our implications and offer recommendations for the scholarly community. Finally, Section 6 concludes with the main findings.

2 Theoretical Background

2.1 Vehicle-to-grid

Since its introduction more than 25 years ago by Kempton and Letendre (1997), vehicle-to-grid has attracted the attention of many researchers – especially in recent years due to the increasing use of electric vehicles (Kester et al., 2019). V2G refers to the use of electric vehicles as distributed storage resources that can feed energy back to the grid to help integrate intermittent renewable energy sources (Kempton and Tomić, 2005). In other words: Electric vehicles can perform smart charging and discharging as soon as they are connected to the grid. Figure 1 shows a schematic representation of V2G. EV drivers plug their car into the charging station, which enables the bidirectional flow of electricity (see black arrows). To set preferences, including the desired minimum state of charge for a given day, or to schedule trips, users communicate with their vehicles (the information flows are depicted as gray dashed lines). This is usually done via an app that connects EV users to the aggregators and the grid (Nuvve, 2022; Saxena et al., 2023). As soon as users connect their car to one of the V2G-capable charging stations, the software takes control of the charging and discharging process. The aggregator makes sure that the session configurations defined by the user are taken into account while offering the available capacities to the frequency-controlled reserve electricity markets. At the same time, the app receives the real-time measurements of the charging session and can transmit them to the user.

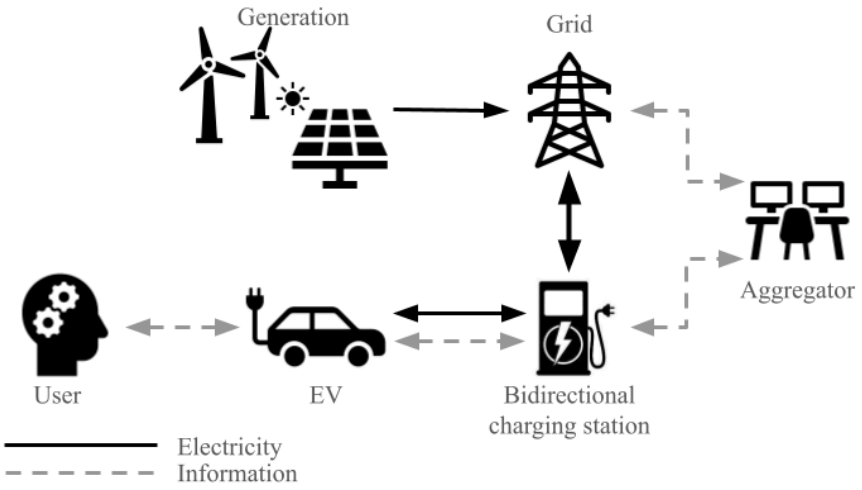

Figure 1. A basic scheme of vehicle-to-grid

V2G has proven to be particularly beneficial for several reasons: First, it can help to leverage the large storage capacity of electric vehicle fleets to provide ancillary services such as frequency regulation, peak shaving, and load balancing (Kempton and Letendre, 1997; Letendre and Kempton, 2002; Hannan *et al.*, 2022). Furthermore, it plays a crucial role in increasing the share of renewables, as this technology can help stabilize the electricity grid in times of mismatch between supply and demand (Kempton and Letendre, 1997).

Along with multiple positive implications of V2G, it has some negative side effects and challenges. Due to more frequent charging cycles, using an electric vehicle for storage needs is associated with accelerated battery degradation, where the degree of the impact depends on the V2G services provided and their frequency (Guo et al., 2019). Apart from that, there are several further technical challenges related to V2G, such as the transmission grid stability, information system resilience (Moghadasi et al., 2022), and payment methods so that EV owners can be rewarded for the energy and flexibility they provide (IRENA, 2023).

Successful V2G adoption requires more than just technical specifications. In particular, it requires the active participation of the vehicle user (Baumgartner et al., 2023). The user should not only give consent to use their vehicle but also interact regularly with the system and make continuous decisions, e.g., about the minimum state of charge that the car must maintain during bidirectional charging, the number and time of allowed cycles per day, the total time connected, etc. So far, however, research has mainly focused on the technical rather than the human side of V2G (Sovacool et al., 2018). Hence, understanding user preferences and motivations is a key factor for a successful expansion of the V2G, as it is the user who will enable the practical operation of the technology. For this reason, this paper investigates the motivational drivers for V2G engagement, contributing to recent publications that focus on user aspects of smart energy systems.

2.2 Self-determination theory

Motivational theories help to understand why individuals are moved to act and able to mobilize others (Ryan and Deci, 2000). One of the best-known approaches, which has dominated hundreds of publications over the last few decades, is the self-determination theory (Vallerand, 1997). It is based on the assumption that people are either intrinsically or extrinsically motivated to engage in certain types of behaviors (Deci and Ryan, 1985). Intrinsic motivation implies that people engage in an activity because they enjoy it and have an inherent interest in it, even in the absence of a reward. Extrinsic motivation, on the other hand, refers to performing a certain behavior in order to achieve a specific desirable outcome (Ryan and Deci, 2000). Inherent in this distinction is the level of autonomy,

which differs for intrinsic and extrinsic motivation. Whereas intrinsic motivation is based on a sense of volition, extrinsic motivation is considered to be controlled, i.e., people feel more or less compelled to do something (Gagné and Deci, 2005). Extrinsic motivation itself varies widely in its relative levels of autonomy, including for example personal endorsement or compliance with external regulation. To detail these distinct types of extrinsic motivation and to capture the degree to which motivation is self-determined, Deci and Ryan (1985) introduced organismic integration theory or rather the self-determination continuum (see Figure 2).

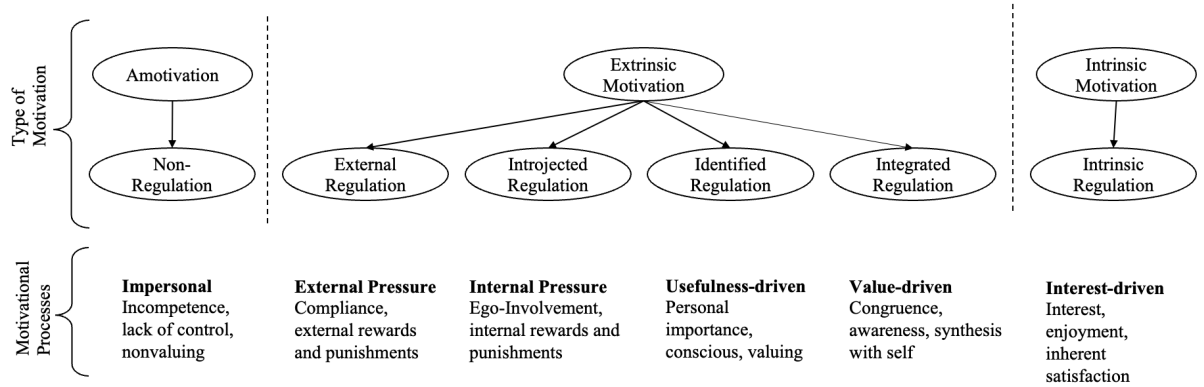

Figure 2. Self-determination continuum (Ryan and Deci, 2000)

At the far left of this continuum is amotivation, which is the absence of any intentions to action. This may include feelings of incompetence or a lack of control. On the far right of the continuum is intrinsic motivation, which represents highly autonomous and self-determined behaviors. Between the two ends, extrinsic motivation is classified into four different categories, starting with external regulation, followed by introjected regulation, identified regulation and integrated regulation. The first category, external regulation, encompasses behaviors aimed at achieving or avoiding a specific externally imposed outcome, such as preventing punishment. Introjection refers to behaviors where individuals have taken in, but not fully accepted some form of regulation. Introjected motivated individuals perform actions to avoid anxiety or to feel pride. In the third category, actions are determined by identification with external regulation, which means that actions are valued and seen as personally important. With integrated regulation, people feel that what they are doing is integral to who they are and therefore critical to achieving personal goals (Ryan and Deci, 2000). Applied to the context of smart energy, specifically V2G, the self-determination continuum provides insights into how people respond to such systems and helps us to explore factors that facilitate or hinder user motivation.

3 Analysis of Vehicle-to-Grid Motivators

3.1 Systematic literature review

To investigate what drives users to adopt V2G technologies, we rely on a systematic literature review. SLRs help scholars to systematically search for research evidence (Grant and Booth, 2009). They serve as rigorous reviews of existing research results to provide a solid basis for answering the research questions (Levy and Ellis, 2006; Kitchenham et al., 2009). Following Moher et al. (2009) literature searches consist of four phases: Identification, screening, eligibility, and inclusion. The first phase is to identify relevant literature through database searches. This is followed by the screening of records, which is usually done by first reading the abstracts of the articles (Vom Brocke et al., 2015). Third, full-text articles are assessed for eligibility, which usually involves the application of inclusion and exclusion criteria, necessary to ensure the quality of the literature search (Kitchenham et al., 2009). The publications found eligible for inclusion were then used to conduct a forward search, i.e.,

to review additional articles that cited the publication. This allows to extend the knowledge base even further (Levy and Ellis, 2006).

3.2 Procedure

Following Levy and Ellis (2006), we started the identification phase with a keyword search in titles and abstracts. To determine an appropriate search string that is broad, feasible and effective at the same time, it is advisable to use a precise term (Rowley and Slack, 2004). Since the focus of our paper is on users and their motivation to engage in V2G, we conducted a keyword search with many synonyms for V2G, combined with synonyms for motivations using the logical operators "AND" and "OR". The final search string for the literature review was

("v2g" OR "vehicle-to-grid" OR "vehicle to everything" OR v2x AND willing* OR participat* OR accept* AND adopt* OR motiv* OR user OR consumer OR household OR prosumer OR "EV owner").

To extract articles of interest, we limited our search to two different databases: 1) Elsevier's Scopus and 2) AIS eLibrary. Scopus was chosen because it provides researchers with a comprehensive list of energy-related articles, and AIS eLibrary was used because it helps to identify IS-focused, peer-reviewed journal and conference papers. Inclusion criteria were peer-reviewed publications written in English, published between Jan 1st, 2018 and October 31st, 2023. Articles were excluded for the following reasons: 1) the focus of the articles was technological rather than user-oriented, 2) the articles were published in mega-journals, such as MDPI, which are suspected to be of lower quality due to a lax or non-existent peer-review process (Ioannidis et al., 2023), 3) the keyword, such as vehicle-to-grid, is not mentioned in the full-text. The initial search string yielded 435 articles in the Scopus database and 23 articles in the AIS eLibrary. After applying the inclusion and exclusion criteria, 15 articles remained for in-depth analysis, representing 3.3 percent of all papers involved in the search. This number is slightly higher than the numbers found in previous literature reviews (Sovacool et al., 2018). The entire information flow of our literature search is captured in Figure 3.

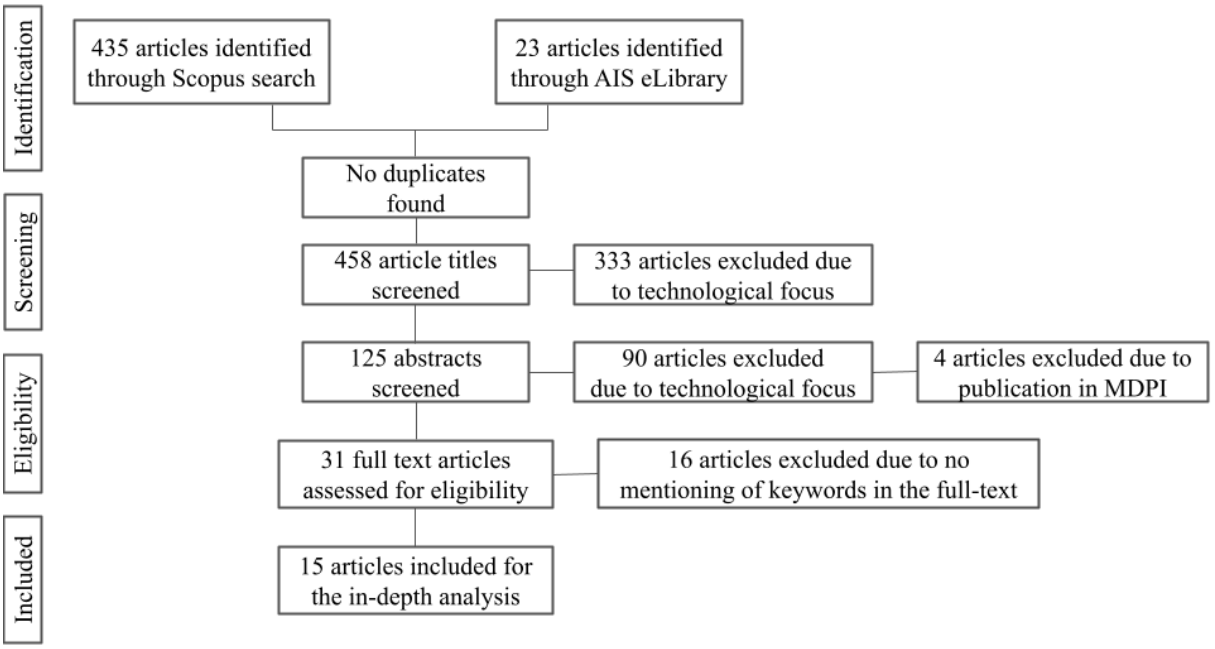

Figure 3. Information flow of literature search

3.3 Results

As depicted in Table 1, they fall into three main categories: The first category relates to studies that focus on the individual level with a focus on individual perceptions, preferences and attitudes. The second category focuses on the individual level, but this time on people's willingness to pay for V2G use. And the third category explicitly covers characteristics of V2G that influence people's engagement with V2G technologies. Below is a brief overview of the articles that were the subject of this study, in order of publication date.

Almansour et al. (2018) collected data from 699 respondents with a Saudi driving license. Based on the participants' preferences stated in the survey, the authors find that a great majority express their interest in V2G technologies. Geske and Schumann (2018) used discrete choice experiments to explore users' willingness to participate in V2G. Their results suggest that both concerns about the minimum range and range anxiety play an important role in V2G engagement. Kester et al. (2019) conducted eight focus groups across five Nordic countries to uncover participant's perceptions of V2G. Their findings indicate that V2G is perceived positively as long as V2G adopters get fair monetary compensation and the V2G features are automated and do not disrupt their travel plans. Noel et al. (2019) implemented a survey among 4602 participants again across five Nordic countries to investigate their willingness to pay for V2G capabilities. Employing a mixed logit model, the authors emphasize that awareness and education of V2G technologies can help accelerate the adoption of electric vehicles. The willingness to pay for V2G capabilities varied among countries and was only significant for Norway and Finland. Another study focusing on Nordic countries is by Sovacool et al. (2019), which examines how geography, income and political affiliation influence perceptions of V2G. Their results show that EV users who live in rural areas, are social democrats, and have an income of up to 50,000 or more than 90,000 Euros are more likely to favor V2G.

A year later, Lee et al. (2020), conducted a web-based survey among more than 1,000 Koreans to investigate their willingness to accept V2G. They find that the higher the rewards for participants, the more likely they are to accept this technology. Based on a sample consisting of 306 Australian commuters working in large companies, Gong et al. (2021) explored attitudes and perceptions toward V2G technology and its implementation in the workplace. Their results reveal the price sensitivity of users. Using context-based choice experiments, Huang et al. (2021) study user's preferences regarding V2G adoption and confirm previous findings on compensation for the time EV users have to plugging-in their EV. Building on the theory of planned behavior, van Heuveln et al. (2021) investigate the user acceptance of V2G technologies. The authors interviewed 20 Dutch EV drivers and identified several barriers, such as user inflexibility or a lack of standards, as well as benefits, such as environmental and compensation benefits, that will determine whether they accept V2G or not. Zhang et al. (2021) collected data from 495 of car owners in England. Based on the stated preferences and willingness-to-pay, they proposed that users value driving range more than flexible access to their cars.

Drawing on a sample of German participants with more or less EV experience, Baumgartner et al. (2022) designed an online survey to explore users' preferences regarding their willingness to pay for a V2G charging tariff and assess the influence of previous EV experience. Their results suggest that more EV experience reduces the need for cost-minimizing charging and increases the need for climate-neutral charging. In the same year, Gschwendtner and Krauss (2022) implemented a stated choice experiment among drivers living in Germany and Switzerland. Benefitting from user's familiarity with EVs, the authors find a preference for V2G carsharing. Building on the work of Lee et al. (2020) and van Heuveln et al. (2021), Medizaneh et al. (2023), surveyed 1000 respondents based in Norway to assess their V2G preferences. Their results indicate that socioeconomic status effectively reduces financial compensation claimed for the use of V2G. In line with previous studies such as Baumgartner et al. (2022), Philip et al. (2023) confirm that experience with EVs, awareness of V2G and knowledge of charging brands play a significant role in the acceptance of such technology. Focusing on Canadian users with EV driving experience, Saxena et al. (2023) investigate users' willingness to participate in V2X programs. Their survey results demonstrate that environmental benefits and financial incentives are the main drivers of V2X participation.

Source	Journal/Conference/Book section	Research focus	Method	Category
Almansour et al. (2018)	Conference on Vehicle Technology and Intelligent Transport Systems	Investigation of V2G based on user characteristics	Survey with 699 participants	1
Baumgartner et al. (2022)	Transportation Research Part D	Exploring user preferences and requirements in the context of a V2G charging tariff	Survey with 1196 participants	1 & 2
Gschwendtner and Krauss (2022)	Transportation Research Part D	Exploring the willingness-to-pay for V2G services	Stated-choice experiments with 308 participants	2
Geske and Schumann (2018)	Energy Policy	Examining individual, technical and economic parameters for the willingness of V2G participation	Survey among 611 vehicle users in Germany	1
Gong et al. (2021)	Transportation Research Part D	Investigation of commuters' perceptions of and attitudes to V2G technology adoption	Dual discrete choice experiments with 306 participants	1
Huang et al. (2021)	Energy Policy	Investigation of EV drivers' preferences for participating in V2G contracts	Online and paper-pencil survey among 148 respondents	1
Kester et al. (2019)	Transportation Research Part D	Examining public perceptions of V2G across five Nordic countries	Eight focus groups with 61 participants	1
Lee et al. (2020)	Transportation Research Part D	Investigation of user's willingness-to-accept for V2G services	Online survey of 1007 interviewees	1, 2 & 3
Mehdizadeh et al. (2023)	Energy Policy	Investigation of concerns regarding V2G and the effects of monetary incentive on acceptance of V2G technology	Survey among 1000 Norwegians	1
Noel et al. (2019)	Energy Economics	Analysis of willingness to pay for V2G capabilities	Choice Experiments among 4602 respondents	1 & 2
Philip et al. (2023)	Transportation Research Part A	Examining user preferences regarding V2G capabilities	Discrete choice experiment with 500 survey participants in Australia	1, 2 & 3

Saxena et al. (2023)	IEEE Access	Analysis of the willingness of EV owners to participate in V2X programs	Qualitative and quantitative survey among 124 EV owners	1
Sovacool et al. (2019)	Journal of Transport Geography	Investigation of perceptions and attitudes towards V2G technologies	Bivariate statistical analysis as well as a hierarchical regression analysis of a survey distributed to 5067 respondents	1
van Heuveln et al. (2021)	Travel Behavior and Society	Insights into users' perceptions of V2G technology and their underlying motivation to accept or not accept V2	20 semi-structured interviews	1 & 3
Zhang et al. (2021)	HCI in Mobility, Transport, and Automotive Systems	Insights into people's attitudes towards V2G including preferences and willingness-to-pay	Online survey with 495 respondents	1 & 2

Table 1. An overview of the analyzed articles

Twelve of the 15 papers used quantitative methods with an average number of 1338 participants to investigate user preferences and motivations for V2G. A qualitative approach was followed by van Heuveln et al. (2021) and Kester et al. (2019). They conducted semi-structured interviews (the former) and focus groups (the latter).

Because V2G technologies are not widely deployed, awareness of the technology is also low (e.g., Kester et al., 2019; Mehdizadeh et al., 2023). It is therefore noticeable that many studies work with samples in which the great majority of people have never even heard of V2G (Philip et al., 2023; e.g., Zhang et al., 2021). Knowledge about V2G concepts in the publications under study ranged from 19 percent (Philip et al., 2023) to 66 percent (Gschwendtner and Krauss, 2022). Low awareness of V2G technologies has been identified as a drawback in previous literature, as respondents are psychologically distant with regard to EVs which limits the conclusions that can be drawn from their findings (Rezvani et al., 2015).

4 A Self-Determination Theory Perspective on Vehicle-to-Grid

The systematic literature review revealed various motivational cues for using vehicle-to-grid technologies. This section aims to understand the individual drivers and integrate them along the self-determination theory continuum (Gagné and Deci, 2005). This is a crucial step in helping energy suppliers and other stakeholders decide whether or not to introduce certain incentive schemes to encourage the use of V2G technologies. In addition, the integration of the self-determination theory provides a first comprehensive overview of motivational factors that may help or hinder the adoption of this new technology. In the first step, the researchers examined the articles individually and identified more than 60 motivational statements. The coders then sat together to discuss and clarify the properties of the identified codes. This allowed for greater consistency and hence reliability (Harry et al., 2005). Table 2 depicts which motivational categories along the self-determination continuums are covered by the publications under study.

The first category, amotivation, which reflects the lowest level of user involvement (Vallerand, 1997), is covered by most of the articles. Amotivation means that people generally do not feel ready or competent enough to use V2G technologies. For example, Noel et al. (2019) find that respondents lack knowledge about the benefits which prevents them from positively evaluating V2G capabilities. Similarly, some users fear disruption of their freedom (Gong et al., 2021; Kester et al., 2019). They are therefore reluctant to act only on request, as this makes them feel uncomfortable and out of control (Geske and Schumann, 2018; Lee et al., 2020). Another factor preventing users from engaging in V2G programs is range anxiety, which refers to EV users getting stranded somewhere because their EV does not have enough battery charge (Geske and Schumann, 2018; van Heuveln et al., 2021). Users also mentioned concerns about V2G capabilities that have discouraged them from adopting this technology. These concerns range, for instance, from worries about the mechanical overload (Lee et al., 2020), reduced battery life due to frequent discharging cycles (Geske and Schumann, 2018; Huang et al., 2021; Saxena et al., 2023) and trust issues (Saxena et al., 2023). Upfront and follow-up costs, such as maintenance and insurance, are also seen as an obstacle to implementation (Gong et al., 2021). Lastly, some studies uncovered that inadequate public charging infrastructure (Gong et al., 2021) as well as better alternatives (van Heuveln et al., 2021) discourage people from adopting V2G.

Moving to the right on the continuum, further categories of extrinsic motivation can be seen. The first is called external regulation (Ryan and Deci, 2000) and means that people are externally pushed or feel pressured to adopt V2G. Rewards are one of the main drivers for V2G adoption: Users are motivated either by financial compensations, such as cheaper energy (Gong et al., 2021) or discounts on charging or parking tariffs (van Heuveln et al., 2021), or by fixed remunerations (Huang et al., 2021). However, findings on the effectiveness of financial incentives are inconclusive. Some studies conclude that financial incentives are one of the most important drivers (Philip et al., 2023), while others suggest that their impact is secondary (Huang et al., 2021; Saxena et al., 2023) or not very supportive (Geske and Schumann, 2018). It is worth mentioning that trust in the V2G system influences the demand for financial compensation (Mehdizadeh et al., 2023).

Motivators in the extrinsic category "Introjected regulation" are attributed to internal pressure, such as expectations. People perform certain behaviors without fully internalizing them. For example, they work because they want to feel worthy (Gagné and Deci, 2005). The studies found in the literature search did not include any motivational factors that would fit into this category.

The third category of extrinsic motivation category "Identified regulation" covers motivations that are utilitarian, i.e., individuals perform behaviors because of experienced usefulness and personal relevance (Ryan and Deci, 2000). Indeed, perceiving that V2G is useful has a significant impact on the adoption of V2G technologies (Mehdizadeh et al., 2023). What facilitates things is that users find V2G easy to use (Gong et al., 2021). Other studies suggest that adding V2G capabilities to an EV can increase EV adoption and thereby improve grid efficiency (Noel et al., 2019). Experience with electric vehicles also turned out to be a significant driver of individual's willingness to pay for V2G capabilities (Philip et al., 2023). Similarly, experience with EVs increases people's interest in V2G car sharing (Gschwendtner and Krauss, 2022). And finally, convenience is a driving force behind the adoption of vehicle-to-x (Saxena et al., 2023).

The fourth category relates to value-based motivators, which reflect the values held by individuals. V2G participation, for example, increases when people want to make a contribution to increasing the share of renewable energy and clean energy sources (Geske and Schumann, 2018; Noel et al., 2019), reduce the CO_2 emissions, or perceive that they can give something back to society by using V2G (van Heuveln et al., 2021). Climate-neutral charging also falls under the umbrella of value-based, integrated regulation (Baumgartner et al., 2022). The same applies when people generally perceive the environment as important (Gschwendtner and Krauss, 2022). One study indicated that political orientation also plays a role in V2G preferences. People who identify as social democrats have a clear preference for V2G capacities (Sovacool et al., 2019).

Source	Amotivation	External Regulation	Introjected Regulation	Identified Regulation	Integrated Regulation	Intrinsic Motivation
Almansour et al. (2018)	x	x				
Baumgartner et al. (2022)		x			x	
Gschwendtner and Krauss (2022)	x	x			x	
Geske and Schumann (2018)	x			x	x	
Gong et al. (2021)	x	x				
Huang et al. (2021)	x	x		x		
Kester et al. (2019)	x	x				
Lee et al. (2020)	x	x		x		
Mehdizadeh et al. (2023)		x				
Noel et al. (2019)	x	x			x	
Philip et al. (2023)	x	x		x		
Saxena et al. (2023)	x	x		x	x	
Sovacool et al. (2019)					x	
van Heuveln et al. (2021)	x	x			x	
Zhang et al. (2021)		x		x		

Table 2. Motivational categories covered in the analyzed articles.

Intrinsic motivation, situated at the far right of the continuum, is not covered in any of the publications under study. When it comes to V2G technology, users seem to be using this new technology for more than just enjoyment or interest in the technology itself. Rather, it appears that motivation is always somehow externally induced – be it through preference, experienced usefulness, or alignment with environmental benefits.

5 Discussion

5.1 Contributions

In the following, we discuss the key findings of our research, highlight the implications, and suggest topics for further exploration to better understand the user perspective on V2G technology. There are two major contributions of our work. First, we provide an overview of the state-of-the-art literature on user acceptance and willingness to participate in the V2G technology. In this way, we extend the existing literature on V2G by emphasizing the user perspective, which has not been sufficiently

explored in current and previous work (Baumgartner et al., 2023). Second, we distinguish 60 user motivations in the analyzed articles and classify them along the self-determination theory continuum. These findings are crucial for guiding future research directions and provide valuable insights for policymakers and industry stakeholders to design effective incentive programs and regulations to encourage widespread adoption of V2G technology.

As mentioned above, we analyzed more than 450 articles published in the last five years to gain more insights into the social and behavioral influences on V2G. Most of the existing literature on V2G focuses on studying the technical aspects and economic viability of the technology. Only 3.3 percent of the analyzed articles approach the topic from the user perspective. However, the 15 studies that take a user-centric approach and examine user motivations quantitatively (n=13) or qualitatively (n=2) attempt to understand the joint interaction between technical and social system, which allowed us to further use their results for an evaluation based on self-determination theory (Ryan and Deci, 2000).

Systematizing the motivations along the self-determination continuum reveals that, so far, user engagement with V2G technology is always externally induced. Consequently, intrinsic motivations for the adoption or use of V2G technology do not yet appear to play a role. One explanation for this finding could be that the perceived disadvantages of using V2G, such as battery degradation (e.g., Huang et al., 2021), outweigh the potential intrinsic motivation. However, we believe that it is only a matter of time before the use of this technology also satisfies people's intrinsic motivation. Based on our analysis, we find that users are driven by motives that fall into the categories of external, identified and integrated regulation. Even if we cannot make a statement about the importance of the individual motivations, we can observe that some of them are mentioned more frequently than others. Out of the 15 studies, 13 indicate that financial benefits, such as monetary compensation, cheaper energy, or parking, can motivate the use of V2G (Kester et al., 2019, Lee et al., 2020). However, the extent of their influence has to be treated with caution. It can significantly vary depending on various factors, such as the socioeconomic status of the user, political views, and experience with EVs (Medizaneh et al., 2023, Sovacool et al., 2019). In turn, for identified regulation, several researchers (6 out of 15) identified factors, such as experience with EV and the perception of the usefulness of the technology, as having a positive impact on users' willingness to engage with V2G (e.g., Gschwendtner and Krauss, 2022, Philip et al., 2023). This leads to the conclusion that a certain degree of internalization has already taken place in the context of V2G. This becomes even more obvious in the category of value-based, integrated regulations, where motivators such as climate-neutral charging or contribution to greenification of the energy system (Baumgartner et al., 2022, Saxena et al.,2023), are just as important as financial incentives. Interestingly, we couldn't identify any motivational factors that would fit into the category of introjected regulations and therefore we assume that their impact on the user is negligible. This could be explained by the unfamiliarity of the technology to the general public and therefore no social pressure to use it, nor to feel proud for using it. van Heuveln et al. (2021) observed analogous behaviors, however, further studies are needed to better understand the cause.

It is also worth pointing out the frequency of amotivation mentioned in the articles analyzed. In more than 73 percent of them (11 out of 15), we find obstacles to the adoption of V2G. They range from a lack of knowledge about V2G technology (Noel et al., 2019, Philip et al., 2023) to prejudices or fears regarding the impairment of their freedom of mobility and the negative impact of bidirectional charging on the durability of their vehicle (Geske and Schumann, 2018, Zhang et al., 2021). It appears that these perceptions are primarily due to limited knowledge and experience. In addition, the lack of infrastructure and clear policies hinder users' willingness to engage with the technology (Sovacool et al., 2017), which has clear implications for policymakers (see section 5.2)

5.2 Implications, limitations and future work

The results of this study have implications for researchers and policymakers. First of all, underestimating the influence of users on the successful adoption of V2G can lead to unexpected implementation barriers and resistance. Therefore, it is important to understand the reasons behind user's lack of motivation to participate in V2G in order to address their concerns and thereby promote

acceptance of the technology (Lee et al. 2020). Second, it seems crucial to raise public awareness about the technology and educate potential users on its benefits. This seems particularly necessary since many people fear disadvantages, such as restrictions of their freedom (e.g., Gong *et al.*, 2021), as a result of V2G usage. Clear policies could significantly improve consumer knowledge of the technology (Noel et al. 2019), which would positively impact motivation to engage with V2G. At the same time, it is important to distinguish between user segments when developing policies and V2G expansion strategies (Kester et al. 2019), as it helps to tailor services better to their preferences and needs, thereby encouraging them to use V2G.

As with any research endeavor, our work is not without limitations. At the same time, even our limitations point to new avenues of research and opportunities. The first point to mention is the scope of our analysis. We only considered peer-reviewed articles found on Scopus and AIS eLibrary, excluding MDPI journals. As shown in section 3.3, we found only a limited number of articles dealing with the user perspective on V2G. Therefore, our results are the first important milestone towards the question of what drives user motivation and how it can be reinforced. We encourage other researchers to build on our findings and also conduct a comprehensive analysis, perhaps even including other publishers.

Self-determination theory is used in this work to systematize and better understand user motivations. It considers an interplay of different types of motivation. However, critics argue that it does not fully account for all the complexities involved in behavior related to the social and cultural dimensions (Ryan and Deci, 2000). Recent work has weakened this argument and has shown that SDT is a credible and universal framework that can be applied to the motivations of people from different cultures and backgrounds (Ryan et al., 2022). The studies showcased that for SDT there are no moderation effects between collectivistic and individualistic cultures (Slemp et al., 2020; Yu et al., 2018). Nevertheless, there are cultural differences in EV perceptions (Sovacool et al., 2018) and it would be interesting to investigate whether the non-moderation statement holds true for V2G adoption.

In a further study, it would be helpful to examine the question of user resistance to adopting V2G in more detail. Exploring the relationship between socio-economic and geographic variables as well as assets could deepen the understanding of the form and the reason for resistance to the use of green energy technologies (Kahma & Matschoss, 2017). This information could help find ways to overcome the resistance. It is also crucial to elaborate effective methods to cultivate acceptance among the users and gain their trust. Trust in technology is essential to make users engage and use more of its features (Mcknight et al., 2011; Saxena et al., 2023). Higher trust in the V2G can also lower the demand for financial compensation (Mehdizadeh et al., 2023). Segmentation of users is another topic that needs to be researched further. Individualization of incentives and nudges can be useful to better approach the user (Marxen et al., 2022). Creating distinct user profiles based on demographic or behavioral factors would help ensure the accessibility and usability of V2G for a broader public.

To get a more holistic understanding and complementary insights of user motivations, further motivational theories could be applied. For example, building on Locke and Latham's (1990) theory of goal setting, researchers could gain interesting insights into how setting specific environmental or financial goals help motivate users to engage with V2G and how the environment can enhance their motivation. And, McClelland's (1961) theory of needs could help to better understand the impact of cultural and social factors on the development of achievement motivation.

6 Conclusions

Vehicle-to-grid is a promising technology that can help reach carbon-neutral goals, however, active user engagement is necessary for its successful deployment. Despite the first important findings that shed light on user's motivations, there is a clear need for more research on user preferences and motivations for engagement with V2G. In response to the call for more user-centric research, in this work, we conducted a systematic literature review that included screening of more than 450 papers,

which were reduced to 15 relevant papers for in-depth analysis to identify motivational drivers for V2G adoption and use. In a second step, building on self-determination theory, we systematized 60 identified motivations and found that users' motivations are always externally induced. Users are willing to engage with the technology for more than just personal interest or enjoyment, with financial and environmental benefits being important drivers for adopting or paying for V2G. Lack of awareness and limited experience with the technology together with unclear or non-existent policies, are the main barriers to user acceptance of V2G. To conclude, clear policies, awareness programs, and developed infrastructure are essential for a widespread transition to V2G systems.

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